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The Problem of Soil Erosion in the United States

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The problem of land depreciation by excessive erosion has come to be recognized as an evil of tremendous importance in the United States. Recently, the assertion has come from prominent agronomists, in state after state, that erosion is the most serious cultural problem confronting the users of land. There is now much eagerness to get under way experiments designed to ascertain as quickly as possible efficient, practical methods for slowing down the wastage, in order that these methods may be introduced into the agricultural practices of those regions where the soils are most vulnerable to the attack of this evil process. Within the past two years the Federal Department of Agriculture, coöperating with the States, has established seven regional experiment stations for the purpose of studying the principles underlying erosional processes and for working out practical methods of erosion control. This national program calls for the extension of these experiment stations to nineteen or more major regions (Fig. 1) in which the cost of excessive soil washing is known to be large. At these stations every promising agronomic, forestal and engineering method for minimizing the impoverishing toll are to be tried out on a field scale as quickly as possible.

MAN-INDUCED EROSION

The kind of erosion we are concerned with in this discussion is the accentuated washing of the land which follows the removal

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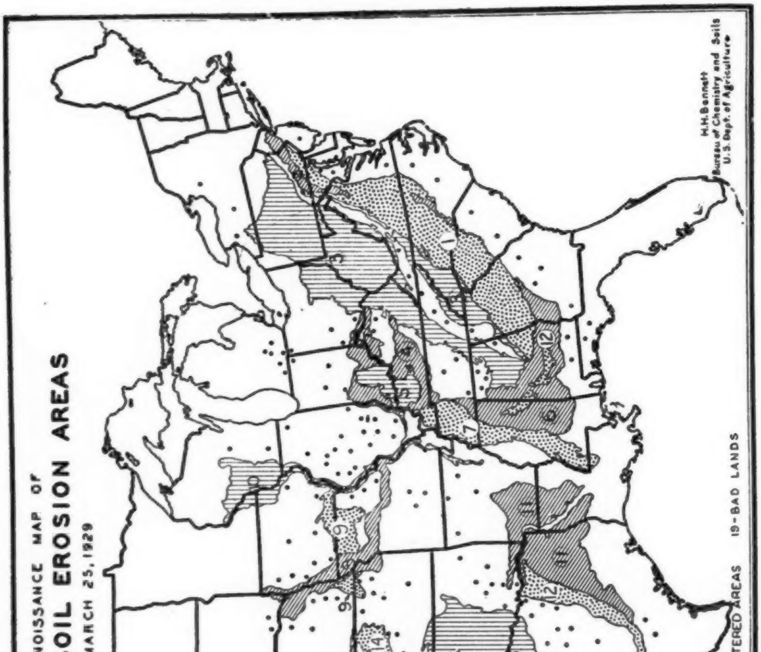
RECONNOISSANCE MAP OF
REGIONAL SOIL EROSION AREAS
MARCH 25, 1929
U.S. DEPARTMENT OF AGRICULTURE
LEGEND
1-PIEDMONT PLATEAU
2-TRIASSIC REGION
3-APPALACHIAN MTN REGION
4-ILL-IND-OHIO-KY REGION
5-IND-KY. REGION
6-MISS-ALA-GA SANDY LANDS
7-SO. BROWN LOAM REGION
8-NO. BROWN LOAM REGION
9-IOWA-MO REGION
10-S.W. WISCONSIN
11-TEX-ARK-LA SANDY LANDS
12-TEXAS BLACK BELT
13-RED PLAINS
14-WEST'N KANS-NEB REGION
15-S.W. VALLEY GRAZING LANDS
16-S.W. MTN GRAZING LANDS
17-SO. CALIF REGION
18-EAST'N WASH-ORE SILTY LANDS
19-BAD LANDS
• SCATTERED AREAS
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U.S. Dept. of Agriculture

FIG. 1

of vegetation and the disruption of the normal ground structure by plows and the trampling of livestock. Briefly stated, it is man-induced erosion, as distinguished from the geologic norm of erosion, which presents itself as a menacing problem of national importance. All of us understand this; we know that the gulleys so frequently observed in abandoned fields, and in some fields which have not yet been abandoned, are not found under normal conditions, either in virgin forests or on well grassed areas. If we turn back to our rural experiences, we can not recall ever having seen the water of summer rains flowing clear from slopes of ordinary farmland devoted to plow crops. We distinctly remember that such water invariably was muddied with suspended soil, red, yellow or black, according to the color of the land from which it flowed. But we can recall, most of us at any rate, having seen clear water or nearly clear water flowing out of woodlands or along diminutive streamways threading lush grasslands. In these recollections we discern some hint of the difference between the erosion which goes on under natural conditions and that which takes place where these conditions have been radically disturbed.

Turning again to our rural experiences, we doubtless can recall that if the fields and abandoned fields passed by were not scarred with gulleys, our conclusion was, if we thought of it at all, that erosion was of no particular seriousness in those areas. In that assumption we were very much in error, as will be pointed out later.

THE IMPORTANCE OF NATURE'S STABILIZERS

Nature employs many implements in protecting the land from rapid washing. To cite one: at the Soil Erosion Experiment Station in the rolling Red Plains (Fig. 1) near Guthrie, Oklahoma, forest-litter was burned from a measured area of oak timber last spring (1930), after the area had been surrounded by a waterproof metal guard, except at the lower end, where all the runoff and washoff emptied into a tank. Another area immediately alongside the burned plot was similarly put under complete control, and the ground with its cover of leaves and twigs left undisturbed as Nature established it. In May of this year, from a heavy, continuous rain the runoff from the unburned plot was at the rate of 250 gallons per acre, while the runoff from the burned plot having the same soil, the same slope and the same vegetative cover was 27,600 gallons per acre. The excess of runoff from the burned plot over that from the unburned plot, plus the water-holding

capacity of its leaf-litter, was approximately 90 tons per acre. The runoff from the former area was essentially clear, while that from the burned-over ground was muddied with the products of erosion.

Thus, the effectiveness of a thin cover of leaves as a protector of the soil is far greater than commonly has been supposed, and, as Lowdermilk has recently pointed out,[2] the chief function of such a ground cover is not merely to absorb water, but to send down clear water into the soil, rather than muddy water, such as would fill up and choke the pore spaces.

SIGNIFICANCE OF THE TOPSOIL

Notwithstanding the fact that the nation has lost at least 17½ million acres[3] of formerly tilled land by ruinous gulley-washing and accompanying deep sheet-erosion, it is not this area of essentially destroyed land that represents the most menacing evil of erosion, but the vastly larger area whose surface is being constantly washed thinner and thinner by sheet erosion. It is essential that we come to a better understanding of the vital importance of the top layer of soil: the humus layer, the principal feeding zone of plants, which we shall designate as the topsoil (or surface soil).[4] Not only are we in need of education in this connection, but we should speed up our efforts to save this topsoil which Nature has taken so long to build. When it is gone, it can not be restored, not in the average field or on the average ranch, at any rate.

The topsoil, the most productive part of the land, is not nearly so deep as is generally supposed. Instead of going "on down without change," as we frequently hear farmland appraised by those who rate soil values on surface appearances only, most of our important upland farming soils have, in the virgin state, a true topsoil depth ranging from about 2 to 12 or 14 inches. Of 172 soil samples representing 115 soil types (nearly all of them upland types), collected from 34 states by the most experienced soil scientists

[2]Lowdermilk, W. C.: "Influence of forest litter on runoff, percolation and erosion"; *Journal of Forestry*, XXVIII, No. 4 (1930).

[3]This estimate is based on soil surveys, erosion surveys and observation. A complete erosion survey of the country may show the area of erosion-destroyed land to be considerably larger that this.

[4]*Topsoil* (or *surface soil*), *subsoil* and *substratum*, as employed in this paper, refer at least roughly, to the *a*, *b* and *c* horizons, respectively, of the Russian system of soil classification. In many instances there is a sub-layer (or subsurface) of the *a* horizon which is much less deficient in humus than the subsoil proper.

of the Bureau of Chemistry and Soils and of the coöperating States, only 7 samples representing the topsoil were taken to depths exceeding 16 inches. The average depth of the 172 surface-soil samples was only 9 inches.

Not only is this topsoil the respository of most of the vitalizing humus, but it is the principal abiding place of beneficial micro-organisms. Moreover, the available analyses show it to be actually richer in phosphorus than the subsoil (due probably to accumulation of this element at the surface in the residuary products of vegetable matter containing phosphorus brought up by deep-going plant roots). The average content of phosphoric acid in the surface soil of the 172 samples referred to amounts to .16%, as against .14% in the corresponding subsoils. Furthermore, the amount of available plant food in the soil is considerably greater than in the subsoil, as indicated by the much better growth crops usually make on the surface soil, as compared with the subsoil, even where the physical condition of the latter is equally as favorable as that of the former (as in the case of Norfolk sand, for example).

In many eroded fields and on over-grazed ranges we have found enormously reduced contents of organic matter as compared with the virgin soils immediately alongside, occupying the same degree of slope. We have also found in many instances lower contents of phosphorus and lime in the eroded areas. These changes have been wholly due to erosion. The soils unmistakably were the same in the beginning.

When the topsoil is all gone, the farmer is forced to operate on subsoil, which not only is less productive, invariably, even worthless in many instances, but is generally more difficult and more costly to cultivate, because of its usual higher content of clay. Such subsoil material is less absorptive of rainfall, as a rule, especially where it consists of stiff clay, as is true of many millions of acres of crop land, and it loses its absorbed moisture much quicker in dry seasons with the baking and cracking characteristic of dense clays containing an abundance of plastic colloids (immature, slightly oxidized clay).

This abnormal erosion is always harmful. Normal erosion going on slowly under the protection of Nature's stabilizers, is not necessarily harmful. It may even have been beneficial over much of the earth. Without it, there is the possibility that a static ground surface would have favored severe leaching or a downward movement of soil particles in percolating water, such as might

have developed vast areas of infertile lateritic soils, on the one hand, and soils underlain by unfavorable, impervious claypans, on the other hand.

It was pointed out previously that the mere burning of the thin cover of forest-litter speeds up the runoff approximately 90 times, under some conditions. The destruction of such a ground cover also puts into operation increased processes of erosion, which if continued, as with repeated burning (Fig. 6), eventually would sweep away the entire surface soil, whose development has required so many years (or centuries).

In this connection, it might be mentioned that the slow rate of surface-soil building under Nature is indicated in the measurements of the Missouri Agricultural Experiment Station, where a 7-inch layer of topsoil (of the Shelby loam type) is removed by washing from land used continuously for corn in approximately 49 years (at the rate of an annual acre-loss of 20.5 tons of topsoil) as compared with about 3,000 years (annual acre-loss of .35 tons of topsoil) required to remove the same depth of surface material from bluegrass sod. Since a good sod of bluegrass is probably a very close approximation of the ground condition under which Nature builds soil in the humid climate of the Shelby soil region, it seems reasonable to assume that corn farming as practiced in northern Missouri and southern Iowa (Fig. 1) is causing soil losses in one year equal to what Nature takes something over 400 years to build.

EROSION OF CULTIVATED LAND

Turning now to the effects of erosion on cultivated land, we find some very significant facts in the measurements made at the erosion experiment stations.

In West Texas on a very extensive and important cotton and grain-sorghum soil, the Miles clay loam of the Red Plains region, the annual loss of topsoil from a 2% slope amounts to 12.6 tons per acre from ground used continuously for cotton, 18.6 tons from fallow, and 3.8 tons from buffalo grass sod. The corresponding losses of water by runoff were 19.5% of the annual rainfall from cottton, 32.6% from fallow, and 6.1% from grass. The maximum annual loss of topsoil was 40.7 per acre from fallow and 27.9 tons from cotton in 1926,[5] the maximum corresponding

[5]The precipitation causing these maximum losses amounted to 27.99 inches, falling during the period of June 18 to December 31.

losses of water being 48.7% of the rainfall from fallow and 28.2% from cotton.[6]

On the Shelby loam, an important and extensive glacial-drift soil of the Corn Belt, the Missouri Agricultural Experiment Station reports the following rates of erosion and water losses from a 3.6% slope, the measurements representing 12-year averages: topsoil lost from fallow ground (cultivated 4 inches deep), 44.4 tons per acre per year; from continuous corn, 20.5 tons; and from bluegrass sod, .35 tons; runoff from fallow ground, 32.63% of the rainfall; from continuous corn, 32.02%, and from sod, 14.21%.[7]

At some of the other stations the losses have been even greater. For example, on May 10, 1930, a single rain caused an acreage loss of 23 tons of soil on Houston black clay having approximately a 4% slope, at the Erosion Experiment Station in Central Texas. With the soil went, also, 96% of the rainfall, amounting to approximately 5 inches. This was from a plot 145.2 feet long, closed at the upper end; and, accordingly, not at all necessarily representative of the full violent erosive effect of accumulated water volume, such as gathers toward the lower part of much longer slopes.

EXTENT OF LAND SUBJECT TO EROSION

Topographic maps, soil surveys and field observations indicate that not less than 75% of the cultivated land of continental United States is as steep as or steeper than the area at Spur, Texas, where the annual loss of topsoil from a 2% slope, used continuously for cotton, averages 12.6 tons per acre. On the same basis, it is estimated that between 60 and 65% of all the cultivated land of the nation is as steep as or steeper than that in central Missouri which is losing 20.5 tons of topsoil per acre every year, while planted to corn.

Not all of this vast area of crop land is washing so rapidly as the Texas and Missouri soil types referred to, but most of it is

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[6] Conner, A. B., Dickson, R. E., and Scoats, D.: "Factors influencing runoff and soil erosion," Bul. 411, Texas Agricultural Experiment Station (1930).

[7] Data supplied by Professor M. F. Miller of the University of Missouri. Expressed in inches, approximately 143 tons of the Shelby loam topsoil equals 1 acre-inch, that is when 143 tons of topsoil is washed off an acre of Shelby loam, the surface of that acre is lowered to an average depth of 1 inch. Roughly, a loss of 150 tons of soil per acre is equivalent to a loss in depth of 1 inch per acre, with soils of average texture.

suffering from erosion in some degree and, unfortunately, much of it is losing its topsoil even faster than those types, according to actual measurement.

Probably not less than 60 or 65% of all the upland in the Piedmont country (Fig. 1—Eastern Appalachian Region, comprising about 50 million acres), which has been or is now in cultivation has lost from around 4 to 18 inches of its topsoil and subsoil. In many localities through this region the characteristic slope is incised with gulleys, even in the case of ancient fields now covered with pine. Many of these gulleys have cut down to bedrock.

A soil survey of Spartanburg County, South Carolina,[8] has shown that 297,216 acres in that county alone have been largely stripped of the surface soil by sheet erosion. The areas so affected are distributed as follows: 209,152 acres of Cecil sandy clay loam, 66,688 acres of Cecil clay loam, 11,392 acres of Cecil gravelly sandy clay loam, 5,184 acres of Louisa sandy clay loam, and 4,800 acres of Louisa clay loam. Practically all of these types, constituting 56% of the area of the county, are new soils, in the sense that subsoil material has been substituted for topsoil material as the result of erosion since the beginning of agriculture in the region. Occasional patches of virgin timber show that the land originally had a covering of brownish-yellow to somewhat reddish sandy loam or loam, about 5 to 10 inches deep. In other words, clay loams have taken the place of sandy loams and loams as the result of a process which sweeps off a portion of the surface soil every time there is rain enough to cause runoff.

But the washing off of the topsoil and the gulleying of the fields of Spartanburg County are not restricted to the types mentioned. The same process has removed the topsoil partly or entirely from many patches through most of the other upland types. Numerous areas, also, have been dissected by gulleys. Moreover, the greater part of the bottom lands, formerly good agricultural soil, has been damaged or made worthless by overwash of sand and gravel and by increased frequency of overflows from channelways choked with the débris of erosion.

This sort of thing has taken place over most of the southern and middle sections of the Piedmont, while sheet erosion, along with some gulleying, has seriously impoverished many fields of the northern Piedmont, as in southeastern Pennsylvania and northern New Jersey. Countless Piedmont areas have been abandoned because of erosion, many having been essentially destroyed, in so far

[8]Latimer, W. J., and others: Soil survey of Spartanburg County, South Carolina; Field Operations, Bureau of Soils, 1921.

as further crop use is concerned. In a single county, for example (Fairfield County, South Carolina[9]), 90,560 acres of formerly tilled land have been mapped and classed as *Rough Gullied Land,* without agricultural value.

EROSION IN THE TEXAS BLACK BELT

Such excessive washing is by no means restricted to the Piedmont. Some of the other major agricultural regions of the country have undergone even more rapid soil depreciation, amounting over numerous areas to almost complete devastation, that is, from the crop-production standpoint. It happens that the subsoil of the more extensive types of farm land in the Piedmont is not so unproductive as the subsoil of many other types in other localities, and can be used with relatively better success, if properly tilled and fertilized. This is due to the peculiar physical character of the subsoil of these lands—the porous, absorptive nature of the highly weathered granite-derived red soils (the Cecil soils).

Agricultural use of the rolling black lands of central Texas (Fig. 1) has profoundly altered the soil conditions in that region. Formerly this was a uniformly black area, with the exception of local exposures of the lighter colored substratum of basal chalk and marl along stream escarpments and along occasional sharp slopes and hill points. Now the region is a mixed black, gray, yellow and white area. Unquestionably, continuation of present farm practices, with accompanying erosion, will convert the sloping parts of this region into gray, yellow and white areas. Even the black stream bottoms, to a considerable degree, will be covered with light-colored overwash from upland exposures of chalk, as already has happened in some instances.

This is the only possible outcome unless effective remedial measures are put into general practice, since the dark topsoil is of limited depth and is being removed at the rate of something like 7 inches in 35 to 40 years (Fig. 2). The original topsoil depth of these rolling areas was only about 6 to 12 inches, being deepest, as a rule, on the gentler slopes. This land was so productive and so deep as found in the depressions and valleys that those farming it made the error of assuming it was all equally deep and all inexhaustible. Already the average farm in these rolling sections has suffered enormously by the increased washing following the breaking of the prairie sod. Some of them have but little of the

[9]Carr, M. E., and others: Soil Survey of Fairfield County, South Carolina; Field Operations, Bureau of Soils, 1911.

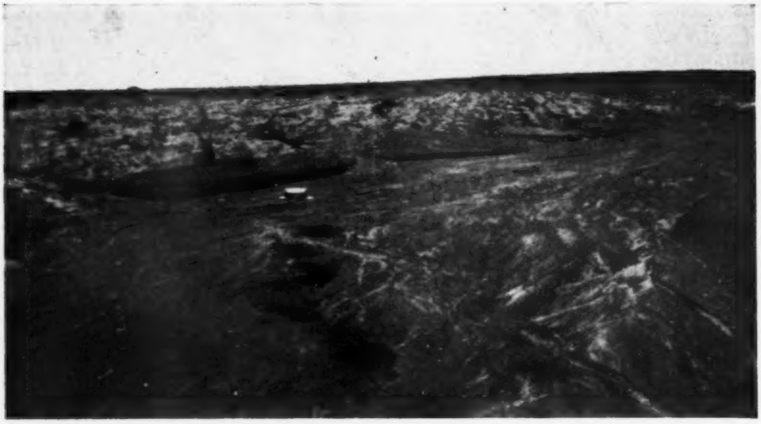

FIG. 2—Every square inch of this large cotton field on Houston black clay 4½ miles south of Temple, Texas, lost a part of its topsoil by sheet erosion during a heavy rain on May 10, 1930. Broad, temporary alluvial deltas were deposited along the lower slopes and later cut out by the same rain. Most of the young cotton was washed out of the ground. From 6 to 8 inches of topsoil were cut away in many places over long strips 100 feet or more across, widening downhill.

original rich, dark topsoil left in the upland fields. Numerous areas have not only lost the dark topsoil, but, successively, the gray, brown and yellow clay layers beneath the surface soil (the *a* and *b* horizons and sub-horizons), on down to the substratum of white chalk from which the soil was derived (the *c* horizon).

Last year (1929), with a dry summer following a wet spring, shallow-rooted cotton was a failure in many small and large fields where erosion had stolen the farmer's principal capital, that is, his topsoil. One large field between Waco and Temple, in the very heart of the Black Belt, gave an estimated yield of one bale to 40 acres. This pitiable crop was not enough, of course, to warrant harvesting. On the same farm some fields, still retaining a layer of the original humus-charged surface soil, produced the same year upwards of half a bale per acre. This year, spring erosion was again exceedingly bad: a wet spring, a dry summer and another almost worthless cotton crop on the severely washed slopes. The rain, near Temple, which removed soil at the rate of 23 tons per acre from land having about the average slope for the rolling parts of the Black Belt, affected not less than three million acres in that region in much the same manner. All of the Black Belt

suffered, as well as the adjacent regions; but the washing on the sloping lands of the former was almost inconceivably severe.

EROSION SURVEYS

The Oklahoma Agricultural Experiment Station completed this year a reconnoissance erosion survey of the State. Of the 15,-781,904 acres found in crops, this survey shows that 13,196,735 acres are suffering seriously from the effects of severe soil washing. Of this eroding area 5,726,452 acres were found to have reached the stage of gulleying, with 374,000 acres (included in fields) so deeply dissected that it is impractical to get farm machinery over the gulleys. Moreover, of 1,694,377 acres of crop land abandoned during the past few years, 1,359,327 acres were found to have been abandoned because of erosion.[10]

The Bureau of Chemistry and Soils has just completed a survey of erosion conditions over the Brazos River watershed, in Texas. Serious erosion has been found, also, over a very large part of this great drainage basin, some counties having been affected to the extent of 90% or more of their cultivated lands.

A detailed erosion survey was made last year of an average farm in the rolling section of the Red Plains, near Guthrie, Oklahoma. This showed that of 160 acres in the tract, 74 acres had been put into cultivation during the past 30 years. Sixty-eight acres, or 92% of this, had lost topsoil and subsoil to depths ranging from about 3 to 96 inches, much of the land having been abandoned. Twenty-five and one-half acres had lost an average of 8 inches of soil, 23 acres had lost 13 inches, 5 acres had lost 20 inches of soil and subsoil, 1¼ acres had lost 42 inches and 1 acre had lost 5 feet of topsoil and subsoil. The Red Plains comprises about 36 million acres, lying chiefly in Texas and Oklahoma. Approximately half of this is much the same type of land as the Guthrie farm, with respect to soil and topography. Wherever this land has been cultivated any length of time nearly every slope shows erosion-exposed clay or gulleys or both.

Quite similar conditions prevail over much of the region of sloping glacial soils in northern Missouri and southern Iowa, that is, in the region of the Shelby soils. The Shelby soils, represented principally by the loam type, in their virgin condition produced from around 65 to 75 bushels of corn per acre, in good years. Now, nearly every cultivated slope shows the impoverishing effects

[10]Data furnished by the Oklahoma Agricultural Experiment Station.

FIG. 3—From this field of Shelby loam, in northeast Missouri, the topsoil has been completely removed by sheet erosion, down to unproductive tough clay. Note the better corn on the gentler upper slope, where a part of the topsoil still remains. Photo made in 1930.

FIG. 4—This is the character of clay exposed by sheet erosion in Fig. 3. It becomes extremely hard in dry weather, cracking and losing its moisture. The topsoil that once covered this "raw" clay produced upward of 75 bushels of corn per acre. This exposed clay usually produces little or nothing. Photo 1930, taken from where the man stands in Fig. 3.

FIG. 5—More than 6 inches of silt were deposited on the flood-plain of this stream (passing through the timber of the background) by one summer flood, which had just subsided. The stream is in the same locality as the eroded area in Fig. 3, and photo was made on the same day.

of excessive washing (Fig. 3). Yellow clay, formerly the subsoil, is exposed in small and large areas and V-shaped gulleys of recent development have come to be a characterizing feature of the landscape of numerous localities. In many fields as much as three feet of topsoil and subsoil have been washed off, leaving material which not only is more difficult to plow than was the mellow loam surface soil, but which dries, cracks and loses its moisture much quicker during periods of drought. The estimated average yield of corn on the more eroded areas, of which there are thousands, is around 20 bushels to the acre. Many of the spots produce nothing in years of unfavorable seasons (Fig. 4). The eroded soil covers up crops on lower slopes and in stream valleys, where the soil covered frequently is just as productive as the deposits themselves (Fig. 5). The price of farmland had dropped tremendously in some parts of this region, two years ago. A typical Shelby loam farm in northeast Missouri sold for $18 an acre early in 1929. This land formerly was valued at about $125 an acre. Report comes from one township of the Shelby soil region, in southeastern Iowa, that something like two-thirds of the farms have been abandoned because of erosion.

Other regions are suffering similar losses. Even Illinois (Fig. 1) reports 9 million acres of low-grade farm land, most of which has been tremendously impoverished by erosion, and 12 million acres of high-grade farm land suffering seriously from erosion, with half the area rapidly approaching the condition of gulleying. Kansas, Nebraska, Wisconsin, Ohio, Indiana, Kentucky, Tennessee, Mississippi, Alabama, and Virginia all include large areas of farm land which have undergone severe impoverishment, considerable areas having been practically destroyed, in the practical, crop-producing sense. In the Valley of East Tennessee recently formed gulleys are almost as characteristic of many sections as any other topographic feature. Much of this gulleying, and along with it a vast amount of sheet washing, is on limestone soil, which at one time rated high as crop land. In some counties of northwestern Mississippi farming has been largely driven from the uplands into the stream bottoms, and the latter have been severely impoverished by overwash of sand and gravel. Clumps of sassafras mark the location of almost countless fields in the plateau country bordering the Bluegrass of Kentucky, which have been abandoned because of erosion. Now we are finding costly erosion in the Washington-Idaho-Oregon wheat belt and in the bean-producing districts of southern California.

SOIL WASHING ON THE WESTERN RANGES

During the past 50 to 60 years a tremendous amount of range land has suffered from severe sheet erosion and channel erosion throughout the ranching country of the Southwest and West (Figs. 1 and 6). On some watersheds, as that of the Puerco River in New Mexico, there is little of the original topsoil left below the line of timber, and practically every alluvial plain has been cut deeply into by recently formed channelways. In some instances the entire valley plain has been eroded away, from the foot of the upland slopes on one side to the corresponding position on the opposite side. These level plains formerly took care of the flood waters that swept down from the foothills and mountains. They were generally well grassed, and the flood waters spread out thinly over them, soaking into the ground. With overgrazing of the uplands and consequent increased erosion, the larger volumes of water rushing into the valleys have cut out channels which are continuously increasing in width and depth. Not only has the grazing capacity of practically all the ranges been largely reduced, except on certain stony lands, but increased volumes of silt are

FIG. 6—Erosion on hillside as result of fire on an overgrazed slope: Coutour trails, vertical "shoestring" gulleys and one great gulley well advanced. Reliz Canyon, Monterey Division, Santa Barbara National Forest.

entering the reservoirs, irrigation ditches and canals. In order to restore any substantial approximation of the original range condition, the indications are that for many of these scalped and gullied foothills and mountain slopes not less than 25 years of complete or partial protection of the land from grazing is the minimum requisite. A few scattered protected areas constitute the standard for this estimate. In reality, exceedingly little is being done to remedy the situation; the depletion of the grazing capacity of an immense area is continuing without let or hindrance. There are many localities where delay with remedial action obviously means a disproportionally increased degree of erosion destructiveness.

WORN-OUT LAND

A very general misconception exists in connection with the possibilities of restoring the productivity of "worn-out land." Most worn-out land is nothing more than eroded land which has lost part or all of its surface soil by sheet erosion. This can not be so readily restored to the original condition of productivity as is commonly supposed. The original soil can not be restored at all, as a matter of fact. With good tillage and liberal additions of organic matter and plant food, however, the yields can largely be increased

in many instances. In some cases it may even be possible to obtain in this way better yields than the original topsoil produced, without treatment. But the cost of the renewal treatment should not be forgotten; and, too, it should be remembered by those farmers who still have in their fields a considerable part of the virgin topsoil that the treatment spent on worn-out land doubtless would also increase the yields on land still retaining its topsoil or part of it.

FIG. 7—Rill erosion on Marshall silt loam, Donophan County, Kansas: result of one rainy period in the fall of 1927, after wheat was up. The wheat was largely washed out of the ground and an estimated amount of considerably more than 40 tons of topsoil per acre was lost by this one rainy period. This is an advanced stage of sheet erosion, such as characterizes washing on soils of high silt content.

When land is broken, not only are the vegetative stabilizers destroyed, but the normal porosity or structure of the topsoil is rudely disorganized on many types of land. Following this, obnormal erosion sets in and sweeps away the humus layer, the topsoil, in the course of 25 to 75 or 100 years (Fig. 7), at which time, unfor-

tunately, the process speeds up again on some soils,[11] owing to lack of erosion-resistance in the subsoil material. Moreover, it is at this stage of washing that the development of gulleys frequently begins (Fig. 8).

Erosion is not the result of any single factor. The variables relating to the process are numerous. Soil character exerts a tremendous influence not only on the rate of washing but on the type of erosion. The amount of rainfall and the intensity of individual showers, as well as the time of the year, also cause enormous difference in this rate of denudation. The degree of slope, the kind and density of vegetation, and the use to which the land is put are other factors of major importance. Some soils, as those of a lateritic nature, wash comparatively slowly. The material of these is slow to go into suspension under any condition. Consequently, percolating waters do not pick up and carry down into the subsurface-layers fine particles to fill up and choke the pore spaces of these soils.

SEVERITY OF EROSION WITHOUT GULLEYING

It has been assumed generally that where there are no gulleys there is no erosion. The fallacy of this already has been pointed out. An illustration may not be out of place, however. The Houston black clay, the most important soil of the great Black Belt cotton region of central Texas, does not gulley readily; yet it is one of the most erosive soils of the country. The fact that it suffers chiefly from sheet erosion is due to its physical properties. The fine material of the surface soil goes readily into suspension and undoubtedly quickly chokes the soil openings beneath during heavy rains, thus reducing percolation. This, seemingly, causes much of the water to flow away over the surface more or less equally, thus eroding the topsoil more or less equally.

That the highly silty soils, as those of the Missouri-Mississippi River loessial regions and of the Palouse country in the Northwest (Fig. 1), develop erosional rills (Fig. 7) more than other types seems to be due to a combination of physical characteristics, viz.: the silt particles, being associated with very little clay, as a binder, go readily into suspension, and the surface soil material in the saturated condition, lacking coherence, is easily cut into by

[11]For example, the loam soils found on some of the benches and lower slopes of southern Wisconsin (Boone soils) have very fragile sandy subsoils which wash with exceeding rapidity after the topsoil is gone.

FIG. 8—Very recent erosion in bean field south of Santa Pazo Valley, California. The topsoil has gradually washed off down to the tough sandy clay subsoil, and gulleys are beginning. It is in this region that strip-subsoiling is done to slow down the terrific wastage by washing. This type of erosion precedes that shown in Fig. 9.

running water, thus favoring, under these combined weaknesses, the development of diminutive gulleys, that is rills, over almost the entire surface, their distribution marking the lines of least resistance through the unstable wet soil mass.

Soils with unstable substrata, as loose sand and soft, decomposed rock, develop caving types of gulleys, which are always exceedingly difficult to control. Soils with impervious clay subsoils, on the other hand, develop V-shaped gulleys, which are much easier to control, as a rule. Those soils having substrata of exceptionally high silt content yield readily to the formation of deep gulleys with vertical walls. This is notably true of the Memphis silt loam and similar types of the loessial country skirting the Mississippi and Missouri Rivers. The substratum of the Memphis silt loam, beginning at depths at about 8 to 10 feet below the surface and containing in the neighborhood of 80% of silt particles, has an erosion ratio of about five times that of the layer above, constituting the subsoil proper, which contains only about 60% of silt and considerably more clay.[12]

In certain soils having compact strata in the subsoil, as the

[12]H. E. Middleton: "Properties of Soils which Influence Soil Erosion"; *Technical Bulletin* No. 178, Bureau of Chemistry and Soils, March, 1930.

Grenada silt loam of the lower Mississippi loessial region, comparatively shallow gulleys readily form, and these frequently extend laterally about as rapidly as in the direction of their heads, devastating the land like a rapidly spreading cancer. Soils with tough sandy clay subsoils or substrata, such as characterize much of the Grenada and Lexington soils of the lower Mississippi loessial region and certain western soils, give rise to a peculiar pinnacle pattern of worthless land, following removal of the upper layers (Fig. 9).

FIG. 9—Erosion in Lampoc Valley, south of Santa Maria, California. This tough sandy clay substratum is riddled with squirrel holes, which have contributed to the washing off of the sandy loam surface soil. This is typical of the pinnacle pattern of erosion characterizing soils having tough sandy clay subsoils.

It is unnecessary to discuss these variables in further detail at this time, but it is pertinent to know that any program designed to slow down soil wastage calls for a tremendous amount of research work in order to deal adequately with this multiplicity of factors relating to erosion processes, as they vary from place to place.

THE PRODUCTS OF EROSION

Not all of the products of erosion go directly into the oceans. These materials are distributed all along the route, from the point

of origin to tidewater. The larger proportion comes to rest, temporarily or permanently, on lower slopes and in reservoirs and harbors. Some cultivated areas occupying depositional plains and lower slopes are benefited by the deposits, the soil being refreshed by the addition of productive silt and clay. A greater part of the material, however, affords little or no benefit, since it is laid down over soil already highly productive, such as the exceedingly rich black alluvium in the stream bottoms of the loessial regions of the North-Central States (as the Wabash soils). Still other deposits, such as water-assorted sand and gravel, and wash from unproductive eroded areas, lower the productivity of the slopes and depositional plains over which they are laid. Indeed, much highly productive alluvial land has been ruined by overwash of sand and gravel, and some streams, as the Coldwater and Tallahatchie of Mississippi, formerly navigable, have been so choked with erosional débris, it now seems incredible that boats ever plied them. To illustrate: more than half of the recent alluvial lands of the Piedmont country, between New York City and Montgomery, Alabama, have been buried with sand and other materials to depths ranging from several inches to 6 feet or more, since the beginning of agriculture in that region. Much of this has been classed and mapped as *Meadow* by the Federal soil survey: a semiswamp type of land, usually covered with willow and alder, and having little agricultural value, other than scant grazing. These relatively infertile, water-logged areas have taken the place of rich loams and sandy loams, largely cultivated at one time. In other words, the good land of the pre-agricultural stage has been buried and made worthless or practically so by the products of erosion. The channelways have been clogged over long stretches, and overflows have become much more frequent and more prolonged.

The classification, *Meadow,* has been mapped in various parts of the United States to the extent of 4,683,750 acres. In the Piedmont section of South Carolina 269,440 acres of recent alluvial land has been mapped in twelve counties, and of this, 210,752 acres, or 72.2%, has been classed as *Meadow.*

We find the following statement, by McLendon and Crabb, relating to *Meadow,* in the soil survey report on Chester County, South Carolina:[13]

"The bottom lands were highly prized by the early settlers for the production of corn and forage crops. Then overflows were not

[13] McLendon, W. E., and Crabb, G. A.: Soil survey of Chester County, South Carolina; *Field Operations, Bureau of Soils,* 1912, 490.

frequent and rarely destroyed the crops, but as more and more of the uplands were cleared and put under cultivation, floods became correspondingly more frequent and disastrous, until now there is so much risk of losing the crops that nearly all of the bottom lands have been turned out of cultivation. The creek bottoms in most places are badly water logged as the result of the streams being so badly choked with sand washed in from the hills."

Much good bottom land has been covered by sand pouring out from recently developed gulleys and erosion-denuded valleys in many parts of the country. In southwestern Wisconsin where gulleys have cut through, and seriously damaged, even destroyed, formerly good benchland farms, a single one of these recently formed gulches, in Buffalo County, has discharged enough sand during the past ten years to ruin something over fifty acres of bottom land on a farm adjoining the one which was practically destroyed by the cutting of the same gulley. As a result of a single rain this gulch piled sand below its mouth to depths of 8 feet, covering a highway and completely burying wagons, tractors and other machinery.

SILTING OF RESERVOIRS

In the fall of 1929 a flood in the valley of the Rio Grande of New Mexico covered an area of approximately 100 square miles, immediately above the head of water in Elephant Butte Reservoir, with sediments ranging up to 7 feet in depth. A detailed soil survey had just been completed of the overflowed area. The soils were so altered by the deposited material that the survey had to be made over this year. Sands were changed to clays and clays to sands through the process of over-depositing.

With the information obtained from these two surveys, it has been estimated that 96 million tons of sand, silt and clay were laid down along a 40-mile strip of alluvial land immediately above Elephant Butte Reservoir. How much entered the reservoir is not known. Silt surveys made previous to this devastating flood have shown that in this great reservoir twenty thousand acre-feet of soil material were being deposited annually.

The silting of reservoirs presents a problem which, like the wasteful washing of fields and ranges, is not going to be controlled simply by discussing the subject and making silt surveys. It is quite necessary, as a matter of course, to make these studies, as well as other quantitative and process studies relating to the whole problem of silting, about which we know very little. But this is not

enough. There is need of experimental tests of all promising means for slowing down erosion on the watersheds, experiments tied in with important soils occupying various slopes, to be carried out on a sufficiently large scale to determine whether or not practical control measures can be brought into use in a way really to mitigate the evil. In the western range country the silting of reservoirs probably can be reduced considerably by strict regulation of grazing on the critical watersheds, but it may also be necessary to search the world for better soil-conserving, dryland plants to supplement those growing in these regions. And it may be further necessary to work out engineering schemes, such as adaptations of the old Mexican *temporal* system, for aiding in the protection of these reservoirs.

There is much to be learned in connection with this problem of silting. For example, no one has satisfactorily explained why the Lake Worth Reservoir, on the Trinity River near Fort Worth, Texas, built in 1895, has been only slightly affected by silting; while the new Austin Reservoir on the Colorado, at Austin, Texas, completed in 1913, had filled to 95.39% of its capacity by 1926.[14] That the former reservoir has a drainage-basin of only 500 square miles, while the Austin Reservoir has a drainage basin of 38,000 square miles, does not explain the situation at all, since a large proportion of the water in both instances passes over the dam. There is reason to believe that soil differences on the two watersheds has had much to do with this difference in silting—the filling of the Austin Reservoir in 13 years and the practical absence of silting in the Lake Worth Reservoir over a period of 32 years.

INCREASING EXTENT OF LOW-GRADE LAND

While there is no danger of a land shortage in the immediate future of the United States, we are steadily extending the area of poor land and "worn-out land," through the agency of unrestrained erosion (Fig. 10), almost as if this were the objective of American agriculture. It is doubtful if any other nation of historical time has outstripped us in the speed with which we have permitted large areas of crop- and range-lands to become severely impoverished by this process. Certainly, no other part of the Western Hemisphere has come remotely near equalling us in this race.

Of course, we did not deliberately set out to lay waste our agri-

[14] See Paper No. 1720, Am. Soc. of Civil Engineers: "Silting of the Lake at Austin, Texas."

FIG. 10—Sheet erosion by a moderate rain on a gentle Iowa slope. This is purely sheet erosion, the rain having fallen too slowly to develop rills. This type of washing, though slow, eventually removes the entire topsoil.

cultural lands. Nevertheless, we have done so, and are continuing to do it on a wholesale scale. Continuing production of large crops with increasing use of farm machinery, fertilizers, soil-improving crops and improved varieties of crops, along with better cultural practices and never-ending abandonment of worn-out fields for fields still having a cover of the original topsoil, can not be looked upon as any evidence of a slowing down of erosion. Our better soils are largely in use, and in many localities the extent of these originally high-grade lands is being reduced by impoverishing rainwash. Abandonment of cultivated land is going on steadily, as shown by erosion surveys. Many thousands of farmers are now cultivating, to a considerable extent, subsoil or subsurface material from which the topsoil has been washed off. Many of these operators are producing only meagre crops, and their standards of living are necessarily low, even when prices are good. In some localities the soils were none too good to begin with. Now, with the more productive top layer gone or partly gone, the difficulties of production are indeed discouraging. In numerous localities crop yields have fallen, and in many others have not increased,[15] with all the improvements

[15]The acreage yield of wheat for the United States was 13.6 bushels in 1869 and 13.2 bushels in 1929; the yield of corn was 27.6 bushels in 1891 and 26.8 bushels in 1929, with no very definite increase trends through the years between. U. S. Dept. of Agriculture: Yearbook, 1930.

of seed and machinery and increased use of fertilizers and soil-improving crops. Unless better control of erosion is practiced, numerous additional areas are sure to decline in acreage output, especially from now on, since many sloping areas have been in cultivation about long enough for the topsoil to have been whittled down to precarious thinness.

We can not afford to delay our attack upon this vicious form of land impairment and destruction. The problem must be met now for the alternative is to increase greatly the difficulties of solution and to extend greatly our area of impoverished and worn-out land. These are large enough now. Indeed, the problem as it stands is going to take our best brains and effort, persistently applied and robustly supported by business men, geographers, agronomists, soil scientists, engineers and foresters. We can not afford longer to look upon the evil as an unavoidable natural process; and we should not make the mistake of concluding that either improved crop varieties or improved farm machinery is going to meet the requirements. To take any effective part in the combat against this wastage we must direct our improved crops and improved machinery, along with improved cultural methods, specifically against the menacing advance of soil erosion. There must be a tremendous amount of experimental work with cropping and tillage methods to cope with the multiplicity of pertinent variables. A machinized farm is not necessarily safe from erosion. Indeed, it may be, under certain circumstances, even more susceptible to wasteful washing than a farm where cultivation is done with simple horse-drawn or ox-drawn plows. Machines must first be built which are designated to work in opposition to erosional processes, such as terracing machines (some of which are now in use).

The problem is by no means hopeless. It is encouraging that an aroused interest in the seriousness of soil erosion is manifest in most parts of the country. Not only this, but actual measures of control are being taken by many farmers and county agricultural agents in various parts of the country, with excellent results in numerous instances. In Iowa, for example, efficient terraces are now being built on farms where a few years ago the operators had not even heard of this implement for fighting erosion.

Memoir of Cyrus Cornelius Adams

W. L. G. JOERG

Cyrus Cornelius Adams, who died on May 4, 1928, in New York in his eightieth year, was a member of the Association of American Geographers since its foundation, having been elected to the council at the organization meeting in 1904 and having served as its president in 1906. Originally a journalist by profession, he rose to the position he occupied in American geography without having had the advantage of a formal training in the subject but rather as a result of the development of his native bent by wide reading, through which, coupled as it was with the newspaperman's necessarily broad range of interest, he acquired an exceptional and truly intimate knowledge of conditions in different parts of the world.

Mr. Adams was born on January 7, 1849, at Naperville, Ill., when the future metropolis of Chicago 25 miles east was still in its infancy. Left partly without parental protection he was brought up by his aunt and uncle at Bloomington, Minn., near Minneapolis, then still practically on the frontier. Trading Indians were a boyhood memory. Evincing greater interest in the lore of books than in the manual labor of the farm he was able through his uncle's assistance and his own earnings to attend the University of Minnesota, then just chartered, and later the University of Chicago, from which he graduated in 1876 with the degree of A.B.

He had already done reportorial work for the *Chicago Inter-ocean,* on whose staff he continued after his graduation. He was soon selected as New York correspondent of that newspaper. About in 1880 he joined the *New York Sun,* a connection which continued unbroken until 1903. During these many years of strenuous journalistic activity he was increasingly able to win the respect of his associates for his favorite subject, until towards the end of that period he was devoting himself exclusively to geographical editorials and special articles.

A contemporary and eye-witness of what may be termed the heroic age of African exploration, it was natural that the fascination of the gradual unveiling of the interior of the Dark Continent should cast its spell over him. His close attention to that

CYRUS CORNELIUS ADAMS
January 7, 1849–May 4, 1928

development and his wide reading of African literature gave him an authoritative mastery of the subject. One detail is illuminating. Realizing that the geographical periodicals published in German, and especially that edited by Petermann, were indispensable sources of information, he acquired a thorough reading knowledge of that language. His intimate understanding of African conditions, as reflected in a questionnaire interview, gained him access to Stanley, from which grew a long and close acquaintanceship. The geography of Africa remained his specialty to the end, as is implied in the range, both as to topics and as to time, of the publications listed under that heading in the appended bibliography.

Interest in exploration naturally also included the stirring events that were taking place at that time in Arctic exploration. Mastery of the subject again led to contact, which developed into long and intimate friendship, with the chief of American Arctic explorers. On more than one occasion Mr. Adams was Peary's mouthpiece in making his plans known to the world and in publishing the results of his expeditions. The latter is especially true of Peary's crossing of the northern end of the Greenland ice cap, the only technical account of which is that by Mr. Adams in the *Geographical Journal* for 1893. Sir John Scott Keltie wrote him at the time that he had covered the subject so completely that he feared there would be little left for Peary himself to say at the explorer's proposed subsequent lecture before the Royal Geographical Society, which, however, was never given. Mount Adams, on the northern side of Inglefield Gulf (77°38′N. and 67°15′W.), is an evidence of Peary's friendship.

Mr. Adams's geographical work on the *Sun* had early led him to establish contact with the American Geographical Society. He became a member in 1892 and was a Councilor for a brief period in 1894-1895. His close association, however, began in 1902 and at first took the form of part-time assistance in the editing of the *Bulletin* of the society, as its organ was at that time called. This later developed into the assistant editorship and finally the editorship (in 1908), which position he held until his retirement in 1915. The expanding set of the *Bulletin*, which at his urging was enlarged in 1904 from five to twelve numbers a year, and the ever increasing range of variety and interest of its contents, bear witness to his influence during the last decade that preceded its transformation into the *Geographical Review*.

He was especially well fitted for the task of editorship by an earlier venture, when in 1891-1892 he edited the first thirteen

issues of *Goldthwaite's Geographical Magazine* (New York). This journal, which numbered Professors W. M. Davis, R. S. Tarr, and R. DeC. Ward among its contributors, seems to be less known than it deserves because of its broad view of the content of geography. Among the four other geographical periodicals that were being published in the United States when it was started in January, 1891, it could well bear comparison with the two leading ones on the score both of frequency of publication (monthly, in contrast to quarterly in the case of the others), and of the diversity and informational value of the subject matter. During its brief existence (to July, 1895) it was also the only journal in this country stressing the educational side of the subject, as two years were still to elapse before the establishment of a periodical specially devoted to the teaching of geography.

No account of Mr. Adams's activities would be complete without a reference to his special interest in cartography. Normally an aspect of his geographical bent, that interest was stimulated by his close acquaintance with the products of European, especially German, map-making. His desire to raise our standards in cartography is illustrated by two examples of measures that he undertook toward that end. One was the organization of an exhibit of foreign map material, mainly school atlases and wall maps, which was displayed at the American Geographical Society in 1908 and subsequently loaned to many universities and schools throughout the country. The other was the publication of a map of the Catskills on the scale of 3 miles to the inch to demonstrate what could be done in the generalization of our topographic sheets for popular use (see the appended bibliography).

Here, again, the exhibit was not Mr. Adams's first undertaking of the kind. In 1890-1891, as president of the newly created Department of Geography of the Brooklyn Institute of Arts and Sciences, a lecture-giving institution of university extension character that exercised much influence in the cultural life of Brooklyn, he organized an exhibition of geographical publications and apparatus used in illustrating or teaching the subject. The exhibition, of wider scope than that of 1908, counted about 2,500 items from European publishers and United States government bureaus and State surveys, and consisted of maps, atlases, relief models, globes, telluria, textbooks, works of reference, and books of travel. When first held in Brooklyn the exhibit was visited by 37,000 persons; later displays, in Boston under the auspices of the Appalachian Mountain Club and in New York at the American Museum of Natural History, were attended by 12,000 to 14,000 visitors.

To many teachers of geography of the preceding generation Mr. Adams was known as the author of a textbook on commercial geography. Responding to the crying need of the time it dealt not in generalities but in facts. It was for a later period to develop the subject more completely around principles; in this transitional stage Mr. Adams's book provided the concrete material so necessary for the proper development of the subject. Of this textbook a past president of the Association has said: "This text of Adams was a godsend. It gave an opportunity for a host of earnest teachers to bring into the curriculum a subject with limitless possibilities of interest, applying the scientific method in the interpretation of everyday matters of industry and trade. Not that the text *gave* this interpretation. It gave masses of fact, and the teacher and student brought to bear whatever genius they may have had in making geographic interpretations" (J. Paul Goode, in *School Science and Mathematics,* Vol. 18, 1918, p. 236). Professor Henri Hauser, the French economic geographer, spoke of it in the following terms: "In this book there are none of the catalogues of names that usually usurp the title of commercial geography. In the introduction the elements of human geography are given—a veritable little model of its kind. The whole book rests on a geographic basis (soils, climate, natural and artificial ways of communication). Products are discussed in connection with the country in which their production or manufacture is specially prominent. In the statistics normal figures are always presented instead of recent figures, which are often misleading. . . . The characteristics of the different regions are brought out in a vivid way. Maps and diagrams and good photographs really illustrate the text. The French reader will specially look for (and find) an excellent summary of the economic geography of the United States including its colonies and Cuba (this occupies one-fourth of the volume). The other countries are treated briefly but with the same care for accuracy and with the same grasp of the 'conditions that determine the quality and quantity of trade,' and of the relation between the earth and man." (*Annales de Géographie: Bibliographie Géographique Annuelle 1901,* entry No. 158.)

Thus far only Mr. Adams's professional activities have been considered. There can be no more fitting close to an account of his life than to say that, on the personal side, he was the embodiment of kindliness. Kindly himself, he was surrounded by an affectionate and loving family and in his last years, when deprived of the companion of his life and when age had dimmed his mental

powers, was tenderly cared for by a devoted daughter, son, and daughter-in-law.

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